



The Philippine aquaculture industry

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THE PHILIPPINE AQUACULTURE INDUSTRY

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ABSTRACT

The aquaculture sector of the Philippine fishing industry registered the highest growth rate of 12.5% in 1977-1986. The contribution of aquaculture to the total fish production was equivalent to 24% in 1986 compared to only 85 in the early 1970's. In terms of quantity, the mariculture subsector registered the highest growth rate of 10.2% in 1982-1986, whereas in terms of value the brackishwater fishpond subsector showed the highest growth rate of 33%. Meanwhile, freshwater aquaculture production exhibited a negative growth rate due to reduction of activities in Laguna de Bay and the slow expansion in hectarage of the commercial freshwater fishponds.

Research by several agencies concentrated heavily on the culture of milkfish (*Chanos chanos*), tilapia (*Oreochromis niloticus*), Chinese carps (*Aristichthys nobilis* and *Hypophthalmichthys molitrix*), tiger prawn (*Penaeus monodon*), and sea bass (*Lates calcarifer*). Innovations in seaweed, oyster, and mussel farming are also discussed.

Research directions are presented to assure an ecologically sustainable growth in aquaculture with emphasis on countryside development.

PRODUCTION AND DEMAND FOR FISH

Fish is a major source of protein for the Filipinos. Per capita availability based on domestic production is 32-36 kg per year for the last five years (Table 1).

Table 1. Per capita availability of fish based on Philippine production

| | Total Fish Production (mt) | Food Fish Production Component (mt) | Per Capita Availability (kg) |
|------|----------------------------------|--|------------------------------------|
| 1982 | 1 896 983 | 1 591 409 | 33 |
| 1983 | 2 110 230 | 1 788 873 | 36 |
| 1984 | 2 080 268 | 1 731 587 | 34 |
| 1985 | 2 052 111 | 1 701 021 | 32 |
| 1986 | 2 089 484 | 1 732 000 | 32 |

In 1986 total fish production was 2.1 million mt valued at US \$1.7 billion, and contributed 5% to GNP. Of this total the contribution of commercial and municipal fisheries and aquaculture is 26%, 51%, and 23%, respectively. In the early 70's the contribution of aquaculture was only 8%.

Of the three sectors, aquaculture exhibited the highest growth rate of 12.5% from 1977-1986 (Table 2).

Fish, aside from being a staple food and a principal source of protein, is a generator of foreign exchange. From 1982-1986 the export of fish and fishery products registered a growth of 10.3% in quantity and 44% in value, with aquaculture posting a higher growth of 15.4% in quantity and 65% in value for the same period. In 1986 alone the share of aquaculture in the total quantity of exports was 37% while in value its share was 53%.

STATUS OF AQUACULTURE

Recent developments adversely affecting the country's fishing industry such as the devaluation of the peso, the escalation of fuel prices, and the tapering off of catch from traditional marine fishing grounds challenged the industry to shift to aquaculture in an effort to maintain fish production at a level which can meet the increasing demand for fish protein. Aquaculture gained importance because of its fast profit turn over, the stability of its output, the higher value and export potential of its products, and its ability to provide the much needed alternative employment in farming communities.

Table 2. Production of fisheries and aquaculture in the Philippines

| Year | Total (000 mt) | Municipal | | | Aquaculture (000 mt) |
|-------------|-------------------|------------------------|--------------------|--------------------|-------------------------|
| | | Commercial (000 mt) | Marine (000 mt) | Inland (000 mt) | |
| 1977 | 1 509 | 518 | 711 | 116 | 164 |
| 1978 | 1 580 | 506 | 687 | 171 | 217 |
| 1979 | 1 581 | 501 | 683 | 204 | 241 |
| 1980 | 1 672 | 488 | 647 | 247 | 289 |
| 1981 | 1 773 | 495 | 710 | 229 | 339 |
| 1982 | 1 897 | 526 | 708 | 270 | 392 |
| 1983 | 2 110 | 519 | 771 | 375 | 445 |
| 1984 | 2 080 | 513 | 790 | 299 | 478 |
| 1985 | 2 052 | 512 | 785 | 260 | 495 |
| 1986 | 2 089 | 546 | 807 | 265 | 471 |
| Growth Rate | 3.7% | 0.6% | 1.4% | 9.6% | 12.5% |

Contribution of Aquaculture to Fish Production

The most widely practised type of aquaculture in the country is the growing of milkfish in brackishwater fishponds. Within the last 10 years culture for *P. monodon* alone or in combination with milkfish became very popular. Mariculture production is dominated by seaweed production as well as oysters and mussels. The production from fishpens and cages in lakes, rivers, and reservoirs is very significant and the use of freshwater fishponds as a medium of production is gaining momentum. Quantity-wise from 1982 to 1986, of the subsectors of aquaculture, mariculture exhibited the highest growth of 10.2%; brackishwater fishponds, 3.5%; while freshwater production exhibited a negative growth due to the reduction of activities in Laguna Lake. In terms of value, the highest growth was exhibited by the produce from brackishwater fishponds, explained by the fact that fish species produced in these areas, particularly shrimp/prawns and milkfish, command higher prices both in the local and foreign markets.

AQUACULTURE DEVELOPMENT PLAN AND FRAMEWORK

Long Term National Goals

The long-term objective of the government and the Department of Agriculture is to lay the foundation for an equitable, efficient, and ecologically sustainable growth in agriculture. The objective is not only to achieve production targets on a competitive basis, but also increase the real income of the poor in rural agricultural households.

Government creates the policy and institutional framework and provides the necessary incentives for investments, infrastructure, research, and technology. The private sector has been called upon to propel the economic recovery in the countryside. People's participation through farmer institutions are recognized as a key factor in bringing about agricultural development.

The government is trying to achieve these objectives through the creation of a healthy economic environment for farmers to maximize their profits. It provides farmers with land, appropriate technology, adequate infrastructure and irrigation, and an effective market information service. It is providing the landless households and other elements of the rural economy with greater employment opportunities. It is decentralizing government decision-making to the grassroots level.

General Objectives for Fisheries Development

Consistent with the national objective of increased rural incomes, policies in fishing are directed at increasing fishing incomes and providing fishermen/fish farmers with more equitable access to resources and an opportunity to be more productive. However, policies directed towards increased production will likewise be pursued in view of the important role fisheries products played in satisfying the country's nutritional requirements and the need for generating foreign exchange.

Rationale for Aquaculture Development

The potential for expanding aquaculture production in the Philippines is extremely high for the following reasons:

1. There are a significant number of hatchery and grow-out operators with the experience necessary to take the lead in the development of the industry;
2. The aquaculture support service/companies including input suppliers, processors, buyers, and exporters are already beginning to organize and expand their operations to meet the future needs of the industry;
3. Ideal climatic, soil, and water quality conditions exist in many areas;
4. Many indigenous species have life histories which make them ideal for culture;
5. Industry is supported by many academic, research, and training institutions and information services which, if reorganized and refocused to improve their effectiveness, could serve to promote and support accelerated development of the sector; and
6. Available fishery resources can be tapped.

Objectives for Aquaculture Development

The government's objectives for aquaculture development in the next 5-10 years have taken into account the potentials of the sector for future expansion both in (1) meeting the nutritional requirements from fish in the event marine production tapers off at present levels and (2) improving the country's foreign exchange position through the export of major aquaculture products like shrimps and seaweeds. These objectives are:

1. Increased aquaculture contribution to total food fish requirement;
2. Improved incomes for rural families;
3. Improved and efficient utilization of culture areas and accelerated development of underutilized fishponds;
4. Increased utilization of lakes, rivers, other inland bodies of water, and coastal areas appropriate for mariculture; and
5. Increased export of aquaculture produced products.

Strategies and Production Plan

To achieve these objectives, several production, post-harvest, conservation-oriented strategies directed by the private sector are to be adopted:

1. Expansion of culture operations to high value species;
2. Intensification of production in existing brackishwater ponds through improved culture technology;
3. Implementation of efficient post-harvest technology and marketing arrangements;
4. Increasing the productivity of lakes, rivers, and other bodies of water; and
5. Expansion of the participation of the private sector in all aspects of aquaculture.

Actual production from aquaculture in 1986 totalled 471 000 mt. By 1990 planned production is 601 000 mt at a 6.3% growth rate. By 1995 target production is 851 000 mt and is expected to increase annually at 7.2% from 1990-1995.

STATUS OF PRODUCTION TECHNIQUES

Milkfish

Breeding and Seed Production. The artificial propagation of milkfish was a subject of investigation as early as 1973-1974 beginning with experiments on hormonal induction of gonadal maturation (Lacanilao 1973), followed by methods of capturing and holding spawners from

the wild conducted by the research team of the USAID-assisted Inland Fisheries Project (Anon. IFP 1974). Vanstone et al (1977) and Chaudhuri et al (1977) succeeded in inducing the breeding of wild spawners and described for the first time the embryonic development of milkfish beginning with the fertilized egg. Juario et al (1984) in summarizing the results of induced breeding and larval rearing works at SEAFDEC AQD between 1978-1981 reported an actual fry production of a little over 12 000.

Meanwhile, researchers at SEAFDEC AQD monitored the growth of wild-caught fry obtained in 1975-1977 and hatchery-produced fry obtained in 1979-1980, using large floating cages in a marine cove at the final stage of culture. Sexual maturation and spontaneous spawning occurred among the resulting two distinct broodstocks. Spontaneous spawning was observed twice in August 1980, 8 times in May-July 1981 and 14 times in May-June 1983 (Marte and Lacanilao 1986) but the recovery of eggs was very poor. In May-December 1986, however, the research team reported that 27.3 million eggs were collected from 58 spawnings of 180 six-seven year old milkfish with the use of various egg collecting devices. The number of eggs collected from 52 spawnings of the same broodstock in May-June 1987 was 31.3 million by a particular gear composed of an egg sweeper and a hapa nets (Anon. 1987). SEAFDEC AQD is currently developing the technology package that will enable prawn hatchery operators to integrate milkfish fry production using the same facilities. Adopting the Taiwanese technology on spontaneous spawning and fertilization of milkfish in small earthen ponds (Lin 1985) will strongly complement this effort and will bring us closer to the goal of replacing wild fry with hatchery-produced milkfish seeds. Nutrition studies will probably play a greater role in both broodstock and hatchery operations before the end of the century.

Nursery and Grow-out Operation. Milkfish culture in brackish-water ponds follows the traditional practice of providing for nursery, transition, and rearing operations. In some cases, formation ponds are used for additional growth or stunting of fingerlings prior to stocking in grow-out or rearing ponds. The nursery ponds comprise about 1-4% of total production area while the transition and formation ponds constitute about 6-9% of the total production area. Figures 1 and 2 show the lay-out of conventional and modular pond systems adopted by milkfish farmers. Both systems, however, require a good supply of unpolluted water and an elevation adequate to maximize the use of local tidal fluctuations (Fig. 3).

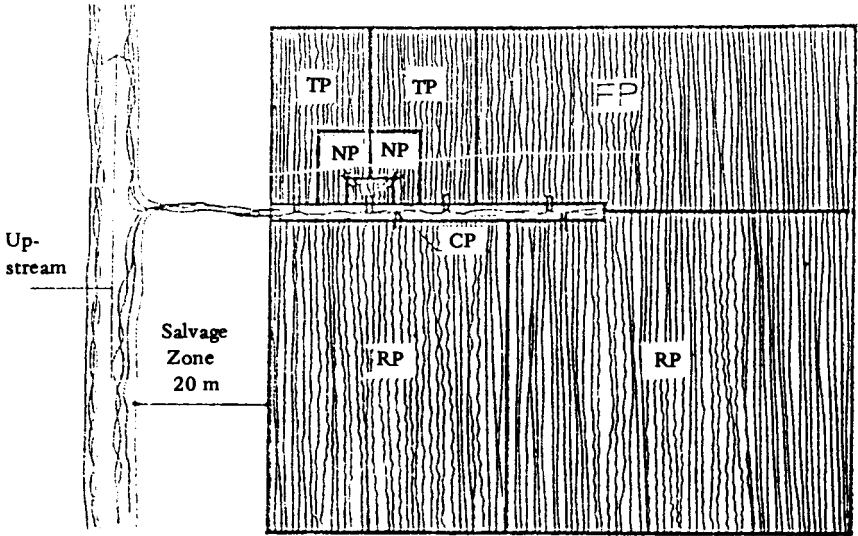


Fig. 1. Conventional system
(Gopa 1983)

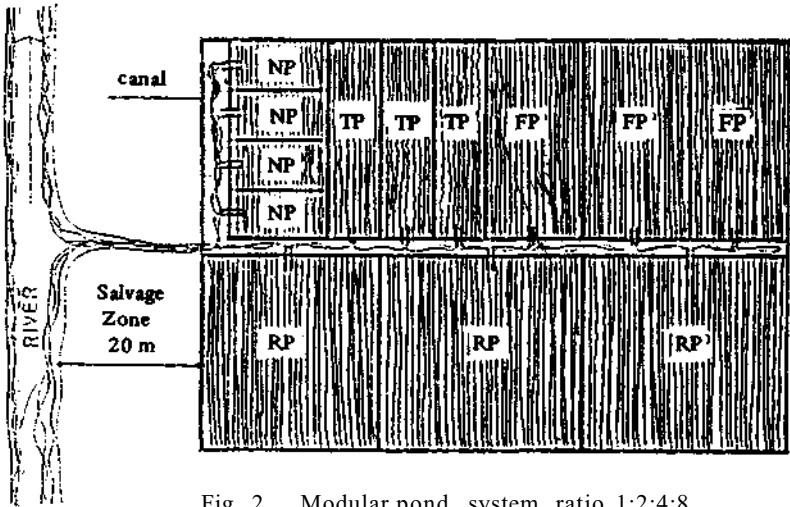


Fig. 2. Modular pond system, ratio 1:2:4:8
(Gopa 1983)

LEGEND:

- NP — Nursery pond
- TP — Transition pond
- FP — Formation pond
- RP — Rearing pond

CONDITION OF TIDE LEVEL

SUITABILITY FOR FISHPONDS

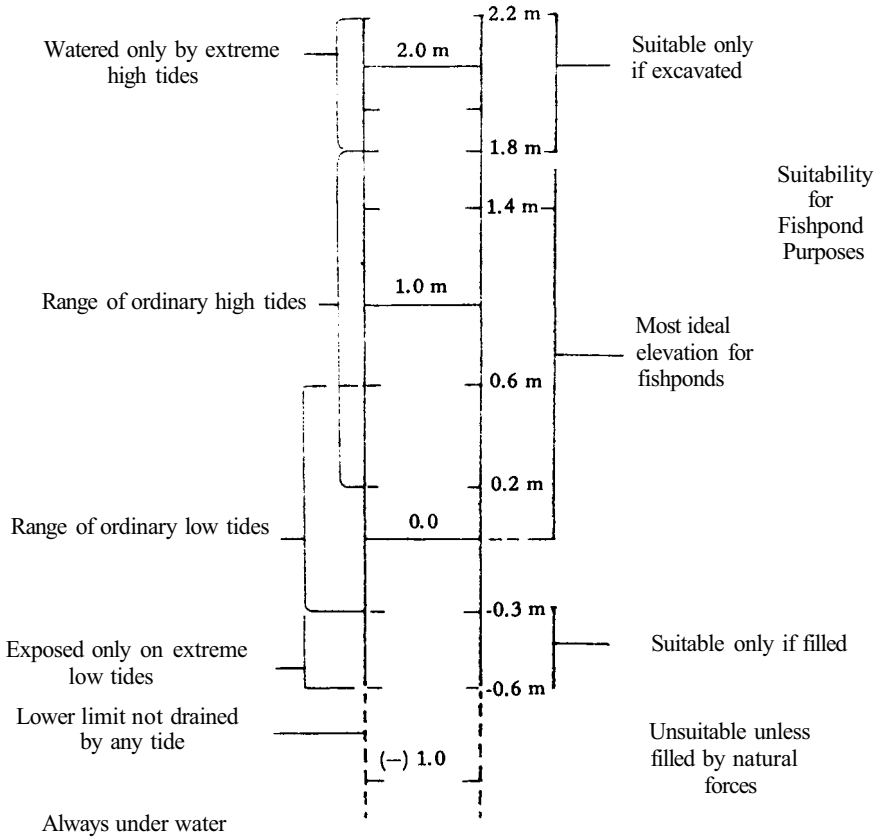


Fig. 3. Relationship between pond elevation and tidal fluctuation (Rabanal pers. comm.)

Milkfish pond aquaculture is basically at the fertilization level of management using *lablab*, a microbenthic plant-animal complex, as food base. In places where salinity ranges are much lower than sea water (less than 10 ppt), *lumut*, a filamentous green alga, is also grown with appropriate N-P-K dosages. The fertilization regimen known to progressive fish farmers is a combination of organic and inorganic fertilizers (Anon. 1976) preceded by lime application particularly in areas of high soil and water acidity. Application of inorganic fertilizer varies in many places and use of chicken manure appears not to be universally accepted by fish farmers (GOPA 1983).

Predator control is considered essential in both nursery and grow-out operations. Drying the bottom after each harvest and the use of fine-mesh nets in sluice gates or pipes are common precautionary measures although the application of chemical pesticides like gusathion, brestan and aquatin is widespread. Biological control using predatory species is recommended but has not been practised on a wider scale.

Milkfish fry stocked at 50/m² in nursery ponds with luxuriant growth of *lablab* will reach fingerling stage of 2-5 g average weight in 4-6 weeks. To grow fingerlings to marketable size of 4 fish/kg would take another 2.5-3.0 months at stocking rates varying from 3 000-5 000 fingerlings/ha. In some of the better-managed fish farms average milkfish yield would reach 1.5 mt/crop. With an organized program of stocking and holding of fry and fingerlings in the modular system it is possible to have 3-6 crops in a year.

Production technology in milkfish farms has brought about significant increases in fish yield and it is believed that further and immediate improvements are attainable with (a) a more systematic arrangements of ponds, (b) renovation or installation of more efficient water control structures of canals, gates, pipes, pumps, (c) repair and reinforcement of dikes, and (d) levelling of pond bottom, excavation of silted areas and clearing ponds of tree stumps (GOPA 1983).

Milkfish is also raised in fishpens especially in Laguna de Bay either in monoculture or polyculture with other species, notably tilapia. At one time fishpens occupied some 34 000 ha of the lake area and contributed about 130 000 mt to the lake's annual output (Mane 1987). Capital investments are considered sizable and yet one could see that there is hardly any real management control over the whole operations. Runoff from the watershed laden with nutrients and agricultural by-products as well as industrial and domestic wastes that are washed into the lake are, however, considered vital factors that enhance lake fertility for fishpen culture. The average annual yield of milkfish from Laguna Lake fishpens was reported to have reached 4 mt/ha/yr at stocking densities of 3-4/m² of enclosed lake area. The current problems and issues associated with pen culture are chemical pollution, massive siltation, allocation of benefits between fishermen and fishpen operators, and the rationalization of multiple uses such as for domestic water supply and flood control (Davies et al 1986).

Tilapia

Breeding and Seed Production. The rapid establishment of small and medium-scale tilapia hatcheries within this decade is a concrete indicator of the growing importance of this species in the country's food production efforts. The current annual fingerling production capability is estimated at 300×10^6 annually (Guerrero 1986) consisting mainly of Nile tilapia (*Oreochromis niloticus*). The ease of spawning is characteristic of tilapia species in general so that earlier research works were concentrated in solving overpopulation (Guerrero 1982).

Nile tilapia fry production methods using net enclosures, concrete tanks, rice paddies, and earthen ponds have been reported (Table 3) and practised by private operators although the efficiency of one system over the other would have to be clarified. Bautista (1987) reported that the use of concrete tanks is the most efficient method except that capital costs and operational expenses are higher. No expanded fry production figures were, however, given. Meanwhile, Guerrero (1987) stocked Nile tilapia breeders in three earthen ponds with areas of 324-415 m² at 4/m² and sex ratio of one male to three females. Total fry production after 30 days was 80 450 or 6.5 fry/m²/day, which may not be an economical operation as actual fingerling production may even be much lower. Earlier studies did not also indicate the spawning potential of each female. Seed production in Laguna de Bay using net enclosures with minimum measurements of 3 × 2 × 2 m appears to be the most accepted scheme considering the natural fertility of the lake. The only drawback here will be the onset of the typhoon season which limits the production cycle.

Genetics and selective breeding will be crucial in the further expansion of tilapia farming. A selection procedure at CLSU Freshwater Aquaculture Center (FAC) has identified a high growth line which was subsequently spawned to produce a new Nile tilapia strain that exhibited a superior growth rate compared with the unselected stock (Abella 1987). The value of interspecific crosses will also be pursued in the near future.

Nursery and Grow-out Operation. The fry production facilities described earlier may also be used to rear the fry to fingerling stage after segregating the parental stock and transferring them into another enclosure or pond. A useful guide regarding stocking densities in the nursery facilities is as follows: 300-500 fry/m² in fine-meshed net (hapa), 1 000 fry/m² in concrete tanks, and 40-50/m² in earthen

Table 3. Comparative production of tilapia hatchery systems (Tilapia Committee 1985)

| Type | Size | Stocking rate (no. of breeders) | Sex ratio (male:female) | Production (no. of fry) |
|---------------|----------------------------|---------------------------------------|----------------------------|----------------------------|
| hapa | 1.5 × 1 × 1 m | 4/hapa | 1:3 | 500/hapa/2 weeks |
| hapa | 3 × 3 × 2 m | 48/hapa | 1:3 | 25/m /month |
| ponds | 1 000-5 000 m ² | 4/m ² | 1:3 | 25/m ² /month |
| paddy | 200-400 m ² | 1/m ² | 1:4 | 100/spawner/month |
| concrete tank | 40 m ² | 4-6/m ² | 1:7 | 80-100/spawner/month |

ponds (Bautista 1987). Fry to fingerling production requires a vitamin and mineral fortified artificial diet containing 30-45% crude protein (Anon. 1985).

Tilapia is raised to marketable size in cages, earthen ponds, and fishpens. Fish cages of the floating or fixed type would vary in size the smallest unit having a dimension of $1 \times 1 \times 1$ m and the larger ones $25 \times 50 \times 5$ m. The cages used in Laguna de Bay consist of bamboo frames and nylon nettings with mesh of 0.6-1.3 cm. Stocking rates of 10-15 g fingerlings vary from 20-25/m² with supplemental feeding. The fish reach marketable size of 100 g each in 4-6 months (Mane 1979). A supplemental feed consisting of 25% fish meal and 75% fine rice bran is offered in dry mash or pelleted form (Anon. 1985). Tilapia is also grown in lake fishpens at densities of 20-50/m².

Commercial culture of Nile tilapia in freshwater ponds is concentrated in the Central Luzon area where extensive irrigation canals for rice-farming provide the bulk of the water supply. The length of the culture period is 4-6 months with an average yield of 900 kg/ha/yr. Annual farm inputs per hectare include 1.8 t of chicken manure, 250 kg of 16-20-0 inorganic fertilizer, and 1.3 t of rice bran and 50 kg of fish meal as supplemental feeds. Stocking rates are 9 000-20 000 fingerlings/ha in a single crop (Guerrero 1987). The technology for rice-fish culture is undergoing some evaluation and refinement considering the incompatibility with the use of agricultural pesticides in rice farming.

The greatest potential for the expansion of tilapia culture is indicated in recent experiments that showed the feasibility of raising Nile tilapia in brackishwater fishponds either in monoculture or polyculture with milkfish (Fortes 1987). Genetic manipulation would someday firm up the prospects of saltwater tilapia culture.

Carp

Breeding and Seed Production. The technique of induced spawning of Chinese carps (bighead carp, *Aristichthys nobilis* and silver carp, *Hypophthalmichthys molitrix*) which was successfully demonstrated in China in 1958 became the subject of further experimentation in a number of countries in the succeeding decades. These carps were introduced in the Philippines in the late sixties but limited knowledge on their seed production and the lack of private sector interest in their commercial culture did not allow the full establishment of a major carp industry. The propagation of Asiatic carps by hormone injection was first demonstrated in 1970 by fishery biologists of the Philippine Fish-

eries Commission (now Bureau of Fisheries and Aquatic Resources) and the Food and Agriculture Organization of the United Nations under the Freedom from Hunger Campaign working with two private hatcheries in Candaba, Pampanga and Dingle, Iloilo (Osborn and Anderson 1971). In 1983-1984 the Binangonan Freshwater Station (BFS) of SEAFDEC AQD concentrated its efforts in the artificial propagation of the bighead and silver carps, using the Chinese technique. During this period 24-year old breeders of bighead carp reared in floating cages and weighing 2.3-2.5 kg each were induced to spawn through injections of 1 800-2 000 IU HCG/kg body weight. Common carp pituitary homogenate was also added at 2-3 pieces of pituitary gland per female. The average fecundity was 150 000 per female with an average fertilization rate of 84.4% but a low hatching rate of 10-30%. It was also found that hatching of eggs was more efficient at 300-500 ppm CaCO_3 hardness. A total of 300 000 fry were produced in the 1984 trials (Anon. 1984). Meanwhile, 25 bighead carps (average weight 3.8 kg) spawned in August-December 1985 producing 577 160 fry. Eggs were fertilized and hatched at the rate of 72% and 25%, respectively (Anon. 1985).

Nursery and Grow-Out Operation. There appears to be no standard prescription regarding techniques of nursing the fry and in the case of Laguna de Bay practices the system used for milkfish is adopted for bighead or silver carps. Raising fry to fingerlings of 1-3 g each in net enclosures (hapa) will take approximately 2-4 weeks taking advantage of the natural food sources of the lake. There is also very little information on nursery management in freshwater ponds, except that the usual application of inorganic fertilizer in combination with manures which was proved to be successful in milkfish works just as well for Chinese carps.

Preliminary data on grow-out operation of pens and cages in Laguna de Bay are available. In one trial (Lijauco and Paraan unpublished), cages made of bamboo frames and B-net (0.6 cm mesh) materials and measuring $5 \times 5 \times 4.5$ m were stocked with bighead carp (12), silver carp (12), common carp (5), and Nile tilapia (250). The initial weights of the fish were: bighead carp (90-197 g), silver carp (0.9 g), common carp (1.0, 9), and Nile tilapia (5.0 g). After 90 days mean weights were recorded for bighead carps at 320-2600 g, silver carps at 100-150 g, common carps at 150-283 g, and tilapia at 48-250 g. The highest growth of bighead carp was close to 19 g/day or 5 times the best recorded growth rate of milkfish.

Another trial (Castro et al 1981) showed the feasibility of culturing milkfish or silver carps as major species in Laguna de Bay fishpens in combination with bighead carp and tilapia. Stocking rates were 3-5/m² for silver carp and milkfish and a constant of 0.1 for bighead carp, 0.5 for common carp, and 1.0 for tilapia. After a period of 4-5 months, the bighead carp exhibited the highest growth of 7.1-10.0 g/day followed by silver carp (5.3-5.7 g/day), milkfish (1.8-2.1 g/day), tilapia (1.1-1.7 g/day) and common carp (0.8-1.3 g/day). The polyculture system with the ratio of 5 silver carp: 1.0 tilapia: 0.1 bighead carp and 0.5 common carp gave the highest net production equivalent to 25.5 mt/ha.

Sea Bass

Breeding and Seed Production. The artificial propagation of sea bass (*Lates calcarifer*), first achieved in Thailand in 1971 by stripping wild-caught spawners, has provided great impetus for its commercial culture. Broodstock from the wild, 2-6 years old and weighing 3-5 kg, are initially transferred and acclimatized under cage or tank conditions for at least 6 months before actual spawning tests (Kungvankij 1987).

Floating cages of variable sizes, 10-100 m² and 2 m deep, may be stocked with broodfish at the rate of 1/m³ of water. Meanwhile, concrete tanks with volumes ranging from 100-200 t can be used with the prescribed stocking rate of 1 fish/2 m³ of water. Good water quality in concrete tanks is usually kept by changing about 30-50% of the water volume daily (Kungvankij 1987). Broodstocks are fed with live or fresh fish during captivity. At SEAFDEC AQD, sea bass broodstocks are maintained in aerated concrete tanks equipped with a special drainage to simulate tidal fluctuations. Fish whose eggs have a diameter of 0.4-0.5 mm, are injected with combinations of homogenized pituitary gland (2-3 mg/kg) and human chorionic gonadotropin (HCG) at 250-1 000 IU/kg. Successful induced spawning was also demonstrated using LHRHa in both injection and pellet implantation experiments (Nacario 1986). Further work is being conducted to improve larval rearing techniques, particularly the methods of culture and preservation of natural feeds such as rotifers (e.g., *Brachionus*), phytoplankton (e.g., *Chlorella*, *Tetraselmis*), and *Artemia*.

Nursery and Grow-Out Operation

Nursery and Grow-Out Operation. In most culture operations the fingerlings are obtained from the wild, although attempts are being

made to mass produce fingerlings from fry produced in hatcheries (Fortes 1987). In one experiment, 7-21 day old sea bass larvae were fed with different types of natural food in an indoor recirculating system. Another study is concerned with the response of fry to formulated diets. Results of the experiments will augment current efforts to culture sea bass fry to the fingerling stage in earthen nursery ponds.

The difficulty of obtaining sea bass fingerlings was met during preliminary growth trials in brackishwater ponds that had to use at least 3 size-groups with mean weights of 8, 24, and 53 g and fewer replicates. In this experiment the slow rate of growth was attributed to delayed response to feeding, i.e., about 49 days from the time the fish were stocked. Low survival rate (35%), meanwhile, was attributed to varying individual sizes of fish which might have led to cannibalism (Fortes 1985).

In another experiment (Fortes 1985) post-fingerlings were raised in cages ($2 \times 1 \times 1.2$ m) for 90 days at stocking densities of 15, 30, 45, 60, and 75/cage. All fish attained sizes adequate for the market at mean harvest weights of 155-240 g.

Prawn

Breeding and Seed Production. In a complete-cycle prawn (*Penaeus monodon*) aquaculture the process begins with 4-6 month old marketable size specimens with 30-35 g average wt, which are further stocked in *broodstock ponds* until the prawn is one year old with an average weight of 9-120 g (Platon 1979). Otherwise, most hatcheries use wild spawners. The biggest and healthiest in the batch are transferred to maturation tanks approximately 12 m^3 and 80 cm deep at the minimum stocking rate of 20 ablated females. When ready to spawn as indicated by the condition of the ovary, each female is transferred to spawning tanks 2 m^3 and 60-80 cm deep that are shielded from direct sunlight and provided with moderate aeration. Temperature and salinity regimes are kept within 27-29°C and 32-33 ppt, respectively. Ablated females in good condition are reported to lay 20 000-500 000 eggs at a time of which 50% will hatch (Primavera 1979).

Ten to fourteen hours after spawning, eggs are carefully transferred to 2-20 t larval rearing tanks at stocking densities of 50-100 nauplii/l. The nauplii undergo several larval molts to reach the post-larval stage within 2-4 weeks. Given adequate natural feeds (Table 4), the resulting post-larvae are stocked in nursery ponds or nursery tanks (Anon. 1984).

Table 4. Recommended feeding scheme for *P. monodon* larval rearing (Working Committee on Prawn Hatchery 1984)

| Stages | Nauplius N _I N _{II} N _{III} N _{IV} N _V N _{VI} | Protozoa Z ₁ Z _{II} Z _{III} | Mysis M _I M _{II} M _{III} | Postlarvae PL ₁ PL ₂ PL ₃ PL ₄ PL ₅ PL ₆ . . . PL _N |
|-------------|--|--|--|---|
| No. of Days | 1.5 days | 5-6 | 4-5 | First day of postlarvae is termed PL ₁ & 2nd day PL ₂ & so on |
| Scheme I | no feeding | <i>Skeletonema</i> or <i>Chaetoceros</i> ; 5 000-10 000 cells/ml | | |
| | | Egg yolk particles; 5-15 particles/ml | | |
| | | | <i>Artemia</i> nauplii; 2-5 <i>Artemia</i> /ml | |
| Scheme II | no feeding | <i>Tetraselmis</i> ; 2 500-5 000 cells/ml | | |
| | | Egg yolk particles; 5-15 particles/ml | | |
| | | | <i>Artemia</i> nauplii; 2-5 <i>Artemia</i> /ml | |
| Scheme III | no feeding | Mixed diatoms; 5 000-10 000 cells/ml | | |
| | | Egg yolk particles; 5-15 particles | | |
| | | | <i>Artemia</i> nauplii; 2-5 <i>Artemia</i> /ml | |

Nursery and Grow-Out Operation. Prawn nursery ponds 1 000 m²-1 500 m² may be stocked with P₁₅-P₂₀ postlarvae at 50-100/m², using the same natural food for milkfish. Platon (1979) stocked nursery ponds at 150 P₅/m² with supplemental feeds.. At water salinity of 20-25 ppt the expected recovery rate of juveniles, P₃₅ with average weight of 1-2 g after 30-40 days, is about 60%. Floating nursery cages, measuring 2 × 5 × 1.5 m, were stocked with P₅-P₁₆ post-larvae at 4 000-16 895/m³ with an average survival rate of 41% (de la Pena et al 1985).

Shrimp grow-out ponds, representing 10-15% of the existing brackishwater fishponds, were originally constructed for milkfish culture. Unique prawn culture requirements, however, would necessitate some form of renovation such as increasing the height of dikes to allow a pond water depth of 1 m, conversion of large units into 5-10 ha sizes, improvement of control gates and the provision of a two-phase nursery grow-out pond systems (IFC 1984). At present, newly constructed shrimp ponds in the Visayan region are small units of 0.5-1.0 ha which are actually converted rice, sugar, and coconut land dramatizing the rapid expansion of the hectarage for prawn production. As shown in Table 5, shrimp farming systems are classified into 3 types, namely, extensive, semi-intensive, and intensive systems (Camacho and Corre 1986). The stocking density for each is much higher than that reported by Apud (1985), indicating that the limits of production technology cannot be determined accurately at this time. The semi-intensive and intensive systems perhaps should be employed with great caution under the present economic situation. Relative to this, a recent study shows that the extensive monoculture of prawn and the extensive polyculture of prawn with milkfish are the only profitable culture systems (Israel 1985).

With greater investments in prawn culture at present, it is important to examine very closely the foreign market situation since under current costs of production domestic per capita consumption has steadily decreased (Camacho and Corre 1986).

Farming of Seaweeds

Only a few members of the green (Chlorophyta), red (Rhodophyta), and brown (Phaeophyta) seaweeds are used for commercial food production or for export. In case of *Eucheuma* and *Gracilaria*, there was intensive harvest of natural stocks especially in the 1960s to fill the

Table 5. Comparison of the three major methods of shrimp culture (Camacho and Corre 1986)

| | Extensive Culture | Semi-Intensive Culture | Intensive Culture |
|-----------------------|--|---|--|
| Pond Size | 5 hectares or larger | 1-8 hectares | 0.25 ha |
| Pond Dikes | Concrete or Earthen | Concrete or Earthen | Concrete |
| Stocking Density (PL) | 10 000-30 000/ha | 60 000-160 000/ha | 180 000-300 000/ha |
| Fry Source | Wild | Wild or Hatchery | Hatchery |
| Fry Size | PL20-PL ₃₅ (25-35 day-old postlarvae) | PL ₂₀ -PL ₃₅ (20-35 day-old postlarvae) | PL ₂₀ (20 day-old postlarvae) |
| Water management | Tidal exchange, no aeration | Tidal exchange and pump with aeration | Pumps, filter, pre-mixed water, paddle-wheels for aeration and water circulation |
| Feed Used | Natural & occasional supplemental feed | Pelleted supplemental feed/natural feed | Formulated complete feed ration |
| Culture Period | 4-6 months | 3-4 months | 3-4 months |
| Harvest size | 25 pcs/kg | 25-30 pcs/kg | 32 pcs/kg |
| Production (kg/ha/yr) | 500 or less | 3 000-8 000 | 10 000-20 000 |
| Survival Rate | 50% or less | 70-80% | 70-80% |
| Crops/yr | 1-2 | 2-3 | 2.5-3.0 |

demand for raw materials in Japan and USA (Trono and Fortes 1985). *Eucheuma* culture was accordingly undertaken in the 1970s to prevent the depletion of resources and to sustain the multi-million industry. The viability of cultivation in Sulu attracted many entrepreneurs and fishermen in the South to engage in the operations such that production of dried *Eucheuma* soared from 400 mt in 1970 to 10 000 in 1974 (Bernardino 1985). At the height of *Eucheuma* culture in Tawi-tawi in 1974 more than 10 000 people were engaged in seaweed farming in more than 1 000 family-type farms ranging from ¼ ha to 1 ha in size (Yutuc and Trono 1977). A family farm covering 0.5 ha of reef area and using nylon monofilament lines to support 7 500 *E. cottonii* plants had a total harvest of 22.5 t wet weight equivalent to a dry saleable weight of 2.2 mt. Each plant grew from 200 g average weight to 3 kg in 90 days (Deveau and Castle 1979).

Seaweed culture represents a very simple system that requires only slight modification of the environment. The farmer provides no control over such factors as water flow and nutrient inputs. Most of the successful farms are located in coral reef areas in Southern Philippines where environmental conditions are relatively stable throughout the year. The net farm installed under water consists of basic net units, usually 2.5 × 5 m, attached to four poles parallel to the bottom. Local farmers have improved the system by using monofilaments rather than polyethylene lines (Deveau and Castle 1979).

The possibility of farming seaweeds in ponds has been explored but the details of commercial application are not well understood (Trono and Fortes 1985).

One serious problem that has faced the industry is the cyclical price fluctuations in the market for *Eucheuma* (FAO 1983). It was reported that buyers, i.e., wholesalers and agents, obtain their annual needs from farmers only early in the year, thereby pushing up prices during that period. These buyers often withdraw abruptly from the market once the annual quota are filled. Other problems confronting the industry in Southeast Asia are presented by Doty (1977).

Oyster and Mussel Farming

Farming methods for oysters and mussels are well established and recent developments are concerned with methods of collecting spats and developing the techniques of growing in areas different from where natural beds are found. Mussels were almost exclusively farmed with

the stake method until the rope-web method was introduced which consists of two 5 m parallel ropes tied 2 m apart between bamboo poles. A 40-m rope is then tied in a zigzag fashion at intervals of 40 cm between knots along the parallel ropes (Anon. 1983). Meanwhile, four methods are used in oyster cultivation: stake, hanging, broadcast, and lattice.

Total production of oyster exceeds 10 000 mt a year predominantly contributed by small farms of less than 1/3 ha thereby indicating the significant contribution of oyster farming in coastal communities (Young and Serna 1982). A single oyster farm with an area of 2 460 m² can produce as much as 4.3 mt or the equivalent of almost 18 mt/ha/year. On the other hand, an average mussel farm of 1 784 m² harvested close to 3 mt equivalent to 8.3 mt/ha/yr (Librero and Nicolas 1979). Young and Serna (1982), however, reported that the productivity in mussel farms, 0.025 — 1 ha, is generally higher than that of oyster farms of 20-68 mt/ha from stake culture to about 300 mt/ha from the hanging method.

The shellfish industry as a whole is facing the problem of environmental deterioration and direct displacement of farming areas by housing and industry. The export potential and to some extent, even local consumption of oysters and mussels, are constrained by lack of adequate sanitation standards and methods.

SUMMARY AND RECOMMENDATION

It could be inferred that were it not for the foresight and dedication of men and women in the academe, government, and the private sector to undertake development research, the aquaculture industry would not be where it is today.

In spite of the numerous research activities completed and presently being conducted there is still a need to intensify and expand these activities. The government's thrust to intensify production of existing and new aquaculture areas would require additional studies on the following:

1. Formulation of appropriate fertilizers for ponds which are suitable to climatic changes, types of soils, and desirable food organisms;
2. Improvement of fishpond design and engineering to provide efficient water management and stock manipulation;

3. Economic viability of various designs of fishponds, fishpens, and fish cages;
4. Research on genetics, genetic engineering, and broodstock development for tilapia, carp, and shrimp considering the importance of fry supply to the development of the industry;
5. Research on culture technologies of high value species, i.e., sea bass, grouper, crab, and abalone as alternatives to presently cultured species like milkfish and shrimp;
6. Culture of non-traditional species low in food chain such as rabbitfishes and mullets;
7. Nutrition, feed formulation, and disease control for larval and grow-out stages;
8. Fry gathering, handling, storing, and stocking to reduce mortality;
9. Use of locally available materials and recycling of wastes to reduce production cost;
10. Post-harvest handling, processing, and marketing to maximize utilization, minimize wastage of fish, and increase returns from aquaculture operations;
11. Culture of fishes, invertebrates, and seaweeds in coastal areas;
12. Expansion of aquaculture areas in freshwater, brackishwater, and marine environment taking into consideration proper land or resource utilization and maintenance of environmental quality; and
13. Stock assessment of fishery resources in coastal and inland waters to complement fish dispersal activities.

Aquaculture research, however, should continue its orientation toward the needs of the industry. Research results should be translated into useful and practical information for the extension workers, industry users, policy makers, and planners. Government and academic research institutions should be encouraged to engage in research that will have a direct impact on the industry's productivity and maximize the profitability of small fish farmers who are the subjects of government's thrusts and programs. The academic, national and international fisheries research institutions must be able to constitute a coherent and coordinated network that pursues specific research goals in conjunction with the commercial, social, and economic development goals of aquaculture.

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